JACC: CARDIOVASCULAR IMAGING VOL. 4, NO. 7, 2011

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC. DOI:10.1016/j.jcmg.2011.01.022

Pitfalls in Plaque Characterization by OCT

Image Artifacts in Native Coronary Arteries

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ONE OF THE GOALS OF INTRAVASCULAR IMAGING IS SPECIFIC IN VIVO IDENTIFICATION OF VULNERABLE PLAQUES, which are likely to cause acute coronary syndrome. Intravascular optical coherence tomography (OCT) is a recent technique that is used for coronary plaque characterization, and is rapidly gaining popularity as a diagnostic tool in catheterization laboratories worldwide. OCT uses infrared light to image arterial wall structure with a high resolution (10 to 15 μm). The appearance of various tissues in the vessel wall has been classified as follows: 1) fibrous—homogeneous signal-rich; 2) calcified—signal-poor with well-defined borders; and 3) lipid-rich—signal-poor with diffuse borders (1). Image artifacts inherent to the technique can lead to misclassification of pathology. Knowledge of systematic confounders in intravascular OCT data may be used to guide image interpretation. In the images presented here, we identify and explain 2 distinct artifacts in OCT imaging, based on ex vivo imaging of human coronary arteries, and show examples of their occurrence in clinical data.

The artifacts, superficial shadowing (Figs. 1 and 2) and tangential signal dropout (TSD) (Figs. 3 and 4), can produce images with the appearance of thin-cap fibroatheroma (2): signal-poor regions overlaid by a thin signal rich layer. The thickness of this layer was measured to be typically 60 to 100 μm, which is very similar to the reported dimensions of OCT-measured thin caps.

In the signal-poor areas caused by these artifacts, the image does not provide adequate information on tissue below the surface. The imaging beam cannot penetrate the vessel wall due to strong scattering or attenuation along an oblique line-of-sight.

Figure 1 demonstrates that superficial shadowing occurs due to a strongly scattering macrophage concentration in the innermost intima (3). In clinical data (Fig. 2), well-delineated radial borders to the shadows were often observed. TSD occurs only in specific imaging geometries that lead to glancing incidence of the OCT imaging beam (Figs. 3 and 4); such sections should be interpreted with care. Some TSD instances observed in vivo exhibited a specific dark radial feature, shown in Figure 5, which we hypothesize to be a result of interface reflection.

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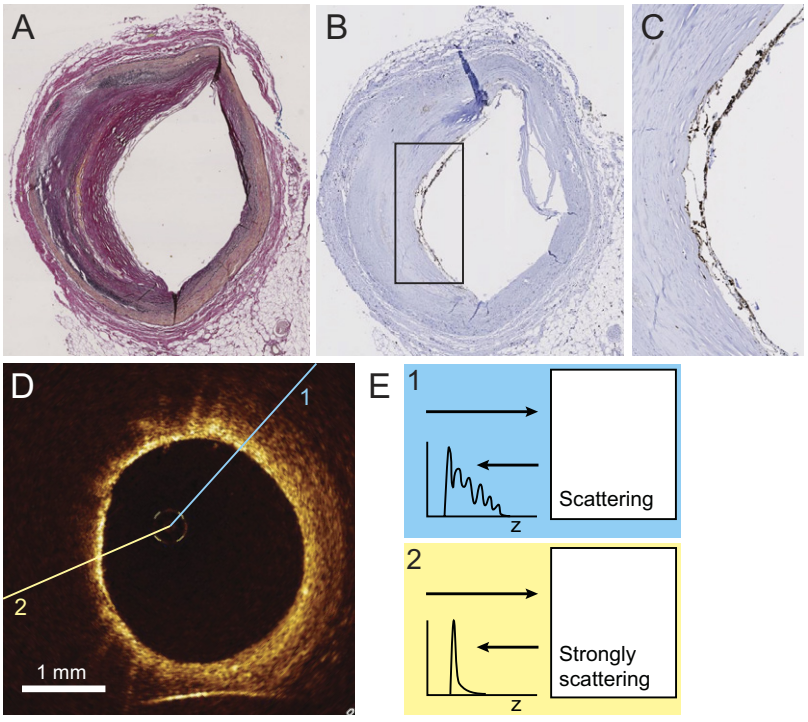

Figure 1. Superficial Optical Attenuation by a Layer of Macrophage Infiltration

(A) Elastic van Gieson stained section showing a fibrotic lesion. **(B)** CD68 staining shows the inner layer of intima is densely infiltrated by macrophages, magnified in **(C)**. **(D)** Corresponding optical coherence tomography (OCT) image, ex vivo. Dense macrophage infiltration creates a highly scattering layer that casts a dark shadow on the tissue behind. This region appears as a thin-cap fibroatheroma (TCFA). **(E)** Schematic representation of the OCT signal along the image lines labeled "1" and "2" in **C**. "1" samples tissue with a moderate scattering coefficient, leading to normal image penetration depth; "2" samples the macrophage layer, which is strongly scattering and rapidly attenuates the OCT beam.

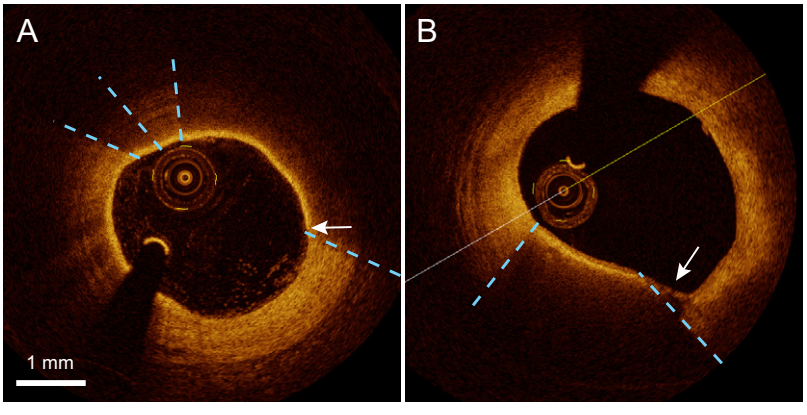

Figure 2. Superficial Shadowing by Attenuation In Vivo

Blue lines indicate well-defined boundaries in the lateral direction, owing to the shadow cast on the deeper tissue by the immediate lumen border. The **arrows** point to the thinnest section of the bright surface layer.

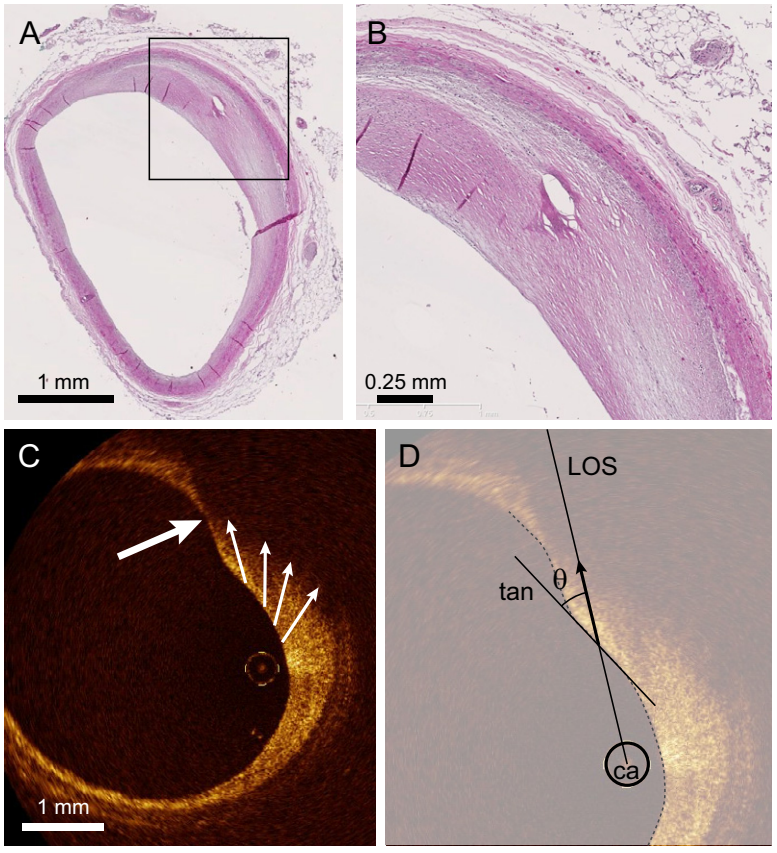

Figure 3. Tangential Signal Dropout

If the imaging beam strikes the tissue under a glancing angle, a signal-poor area with diffuse borders, covered by a thin signal-rich layer, can arise, which appears like lipid-rich tissue covered by a fibrous cap. **(A)** Hematoxylin & Eosin staining. **(B)** Magnification of the fibrotic lesion, misinterpreted as TCFA on ex vivo OCT in **(C)**. The **large arrow** points at the spot interpreted as a thin-cap. If the OCT beam strikes the vessel wall obliquely **(thin arrows)**, the light travels a longer path through tissue to a certain radial depth (relative to the lumen border). The signal at that location is weaker than in a geometry where the beam strikes the interface perpendicularly. **(D)** Schematic representation of the imaging geometry. The OCT beam is directed from the catheter (ca) along the line of sight (LOS). Imaging geometries with a small angle θ between the LOS and the tangent to the lumen contour **(tan)** may lead to tangential signal dropout. Abbreviations as in Figure 1.

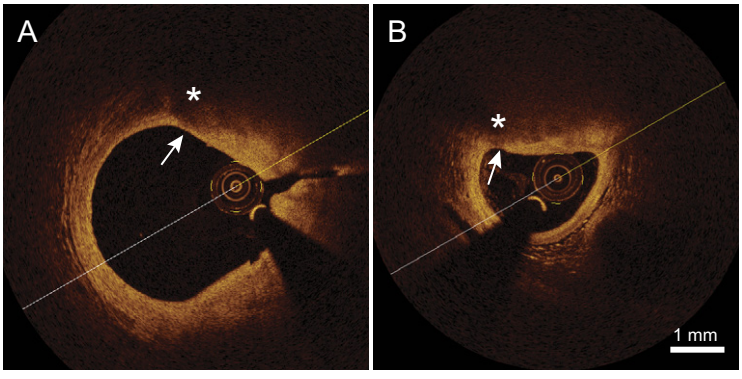

Figure 4. Tangential Signal Dropout In Vivo

The * indicates signal-poor regions at sites with oblique incidence of the OCT beam. **Arrows** indicate the thinnest point on the bright line overlaying the signal-poor region.

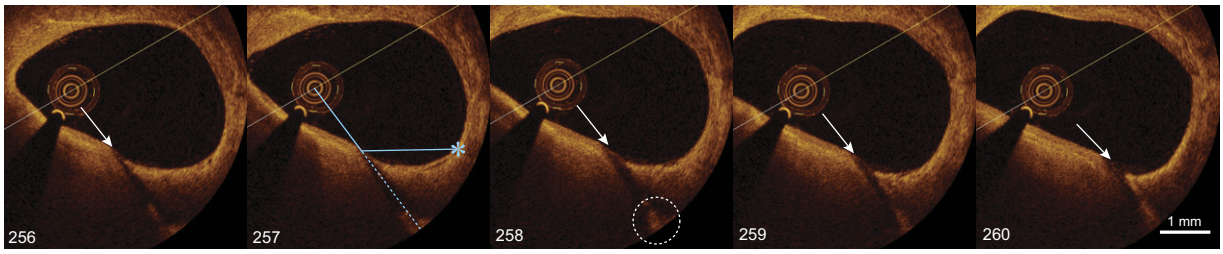

Figure 5. A Series of Frames In Vivo Showing a Dark Radial Feature Occurring at a Site of Glancing Incidence

This feature **(arrows)** could be misinterpreted as a small side branch, but is seen in several consecutive frames, and moves to the right along the circumference of the border. There is a brighter area deep in the tissue (indicated by the **circle in frame 258**, but occurring in all frames). Glancing incidence can strongly enhance surface reflectivity. We hypothesize that the imaging beam is reflected off the vessel wall as sketched in **frame 257**, producing a "ghost" reflection (*).

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